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NAVORD REPORT 2792

DETONATION TRIALS ON A MIXTURE OF ALUMINUM AND LIQUID OXYGEN

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U. S. NAVAL ORDNANCE LABORATORY

WHITE OAK, MARYLAND

DETONATION TRIALS ON A MIXTURE OF ALUMINUM AND LIQUID OXYGEN

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ABSTRACT: The result of two unsuccessful attempts to detonate a mixture of aluminum powder and liquid oxygen in a 2 1/2 inch diameter charge are reported. The composition was stoichiometrically balanced to that of Al_2O_3. The probable requirements for charge size to successfully detonate aluminum-oxygen mixtures to obtain useful data for theory is estimated from the observations.

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NavOrd 2792 reports some preliminary results on attempts to detonate a mixture of aluminum and liquid oxygen. The system would be of considerable theoretical interest if a stable hydrodynamic detonation could be achieved. The results obtained were mainly negative. The experiments will be of interest to those concerned with the theory of detonation. The results are believed to be correct. They are not recommended, however, as a basis for official action. The work was carried out under Task Number NOL-Re2c-1-1-53.

The author wishes to express his thanks to Dr. A.V. Grosse of Temple University, Philadelphia, Pa. for his great interest and cooperation in the performance of these experiments. The assistance of Dr. H. Dean Mallory, Mr. Donald Danielson and Mr. Halcom Curtis in performing the experiments is gratefully acknowledged.

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DETONATION TRIALS ON A MIXTURE OF ALUMINUM AND LIQUID OXYGEN

INTRODUCTION

1. As a result of conversations and correspondence between Dr. A. V. Grosse of Temple University, Philadelphia, Pa. and Dr. J. E. Ablard of the Explosives Research Department, Naval Ordnance Laboratory concerning the detonation of mixtures of aluminum and liquid oxygen, Alox, plans were made for some preliminary experiments to establish whether such mixtures could be made to detonate on a scale which could be handled in our bombproof. We had established that 2 1/2 inch charges were about the maximum we could handle within the 5 pound charge limits for the bombproof if the material were to detonate. Charges of 2 1/2 inch and 1 1/2 inch diameter were therefore proposed for an experiment which combined detonation velocity measurements with a test to determine whether the Alox would propagate a detonation to a second explosive. It was intended that the 2 1/2 inch charges would be tried first since failure to propagate in the large charges would imply that the small charges, too, would not propagate. Success in obtaining a stable detonation velocity in the preliminary tests would lead to an opportunity to apply the hydrodynamic theory of detonation to learn more about the nature of the reaction of aluminum and oxygen at detonation pressures. Details of the analysis, though not worked out, seemed to be capable of being handled. Success in detonating Alox would make it worth the effort to complete such an analysis.

2. On 22 and 23 September 1952, Dr. A. V. Grosse visited NOL and brought several aluminum cases filled with aluminum powder to produce a series of Alox charges in accordance with suggestions given by Dr. J. E. Ablard. These consisted of both 6 inch long by 2 1/2 inch diameter and 8 inch long by 1 1/2 inch diameter cases. Experiments were performed on the 2 1/2 inch charges formed with liquid oxygen. These trials led to the unhappy conclusion that the Alox charges as prepared neither detonated stably nor propagated a detonation to cast Composition B. The experiments were therefore concluded after the second try. It has been established that the failure diameter for Alox charges of the composition used exceeds 2 1/2 inches by an unknown amount. In order to obtain detonation velocity data which can be used for study of the chemical reaction it will be necessary that detonations be carried out in charges of diameters which exceed the failure diameter by at least a factor of two. These experiments have lead us to the realization that the use of Alox as an explosive for theoretical studies will require very large charges; 50 pounds and probably greater.

3. Experimental Procedure. The experimental charge was as follows. Each charge consisted of a cylindrical shell of aluminum 1/32 inch thick, 2 1/2 inch diameter and 6 inch length. The case was drilled with 3/16 inch holes spaced about each inch longitudinally. Longitudinal rows of holes were spaced about an inch apart circumferentially. The cylinder was lined with aluminum foil and the interior was filled with aluminum powder of about 400 mesh. The amount of powder used was such that the mixture of Al and liquid O_2 would be stoichiometrically equivalent to the composition Al_2O_3. An additional 1/2 inch of tube similarly filled with Aluminum powder was added to the length of the tube at NOL so that the tube length would fill the 6 1/2 inch long, 3 inch wide by 3 inch high galvanized trough in which the liquid oxygen was to be contained. Prior to assembly of the charge the aluminum foil was pierced with a needle at each hole so that the oxygen could enter and mix thoroughly with the aluminum powder. The charge train consisted of:

(a) Engineers Special Detonator

(b) 2 1/2 inch plane wave booster

(c) Cast Composition B, booster charge 2 1/2 inch diameter, 4 inch length.

(d) The cylinder and trough to which liquid oxygen was added

(e) Cast Composition B, acceptor charge 2 1/2 inch diameter by 2 inch length

All train components were butted into contact with each other. Item (e) was used to serve as a check on the detonation of the Alox mixture. Initiation of this Composition B acceptor could be taken as almost conclusive evidence that a detonation had propagated through the Alox. Failure to detonate the receiver, on the other hand, would be strong evidence against the occurrence of a detonation.

4. The charge train was set-up in a horizontal plane for detonation velocity measurement with the rotating mirror camera. A mirror tilted at 45° was used to bring the image seen by the camera into a vertical plane. A sketch of the charge, as seen by the camera, appears in Figure 1. Liquid oxygen was added to the trough by remote control from outside the bombproof chamber. Filling was checked by watching the operation through a safety window. The charge was detonated when the oxygen was seen to cover the tube in an undisturbed layer.

5. The results of two attempts are shown in Figures 2 and 3. The streak record of the Composition B detonation was normal in the booster charge. A velocity of 7300 meters per second was calculated for Composition B by rough measurement of the records. This was believed to agree to within the precision of measurement with the published rate at cast density of 7800 m/sec. A wave is observed to start out in the Alox at 1/2 the Composition B velocity, (about 3900 meters per second) but this wave died out after 3 to 4 inches of propagation. The wave was probably a shock and not a detonation. No evidence was found in the records to indicate that the receiver charge was detonated. After the second shot a film of solid material was scraped off the bombproof window at which the detonation was directed. This material was identified as Composition B. A similar film had been observed after the first shot but it was not tested. The evidence is clear that the Alox did not detonate Composition B. Because of the negative results obtained it was felt to be of no further gain to attempt other shots at this time with the described set-up. The two records agreed sufficiently well to be used as a basis for the conclusions drawn.

DISCUSSION

6. It is concluded from the result that the Alox did not detonate completely, if at all. It may at best have been a partial, or failing, detonation. Very rough calculations on the basis of estimates on compressibility of aluminum oxide and the heat evolved in the reaction would lead to an estimate of the theoretical hydrodynamic detonation velocity as being in excess of 5000 meters per second. A much larger charge will be needed to achieve the hydrodynamic velocity. This cannot be fired in our present facilities. These experiments might be undertaken elsewhere as e.g. University of Utah's ONR contract or Dahlgren. However, if these large scale experiments are to prove costly, then before they are undertaken due consideration should be given to first checking on the details of the analysis which will have to accompany the measurements. It is believed that the thermodynamic data are available for performing the necessary calculations to at least a first approximation. This is the next step before further experimentation. Meanwhile this report is being released so that our results will be available to those interested. It is our opinion that unless stable detonation can be obtained it will not be possible to interpret the results in terms of the hydrodynamic detonation theory. The results, then, would also be of little value in a study of the role of aluminum in detonation.

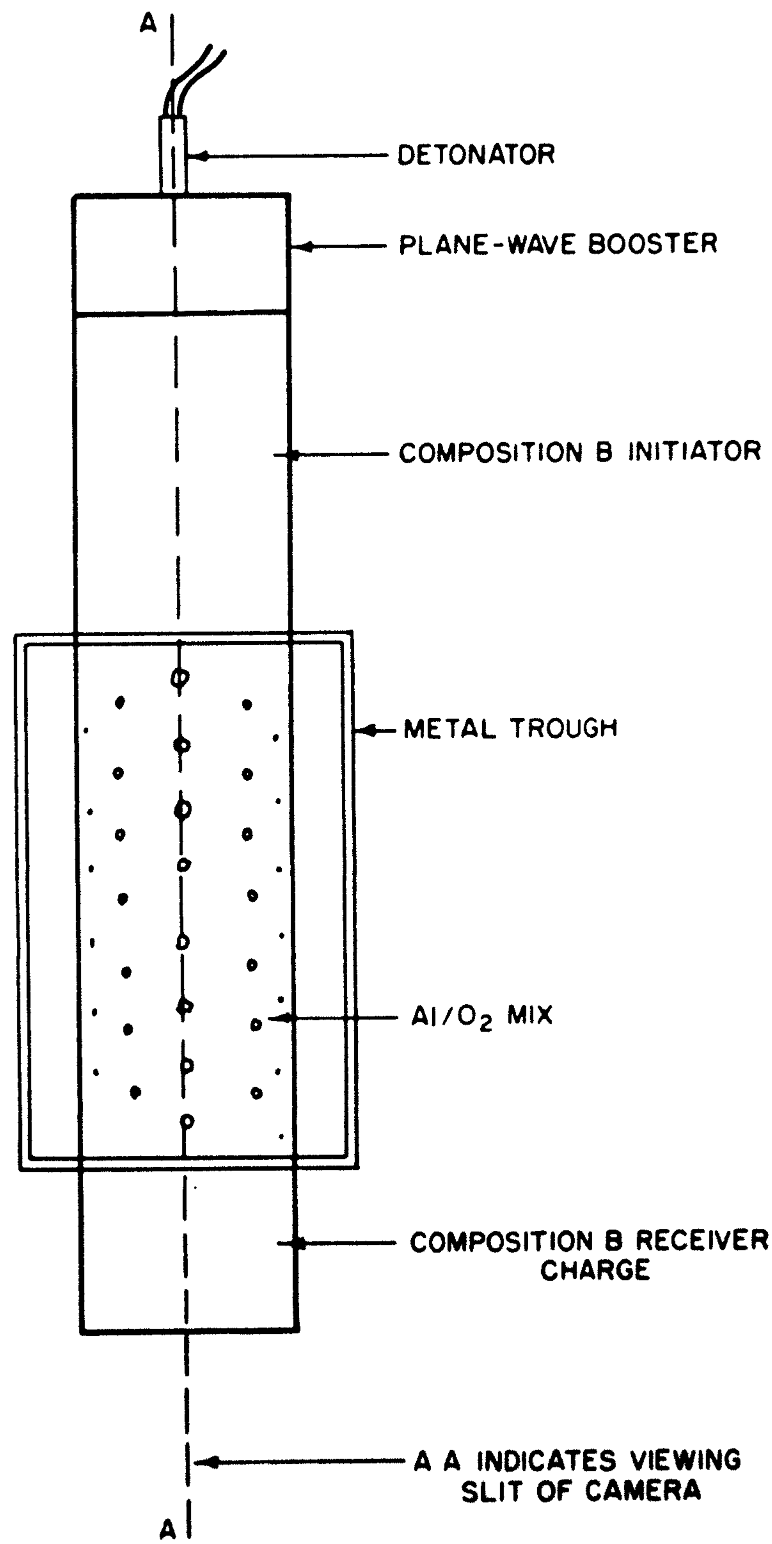

FIG. 1 EXPERIMENTAL SET-UP

FIG. 2 FIRST DETONATION RECORD

FIG.3 SECOND DETONATION RECORD